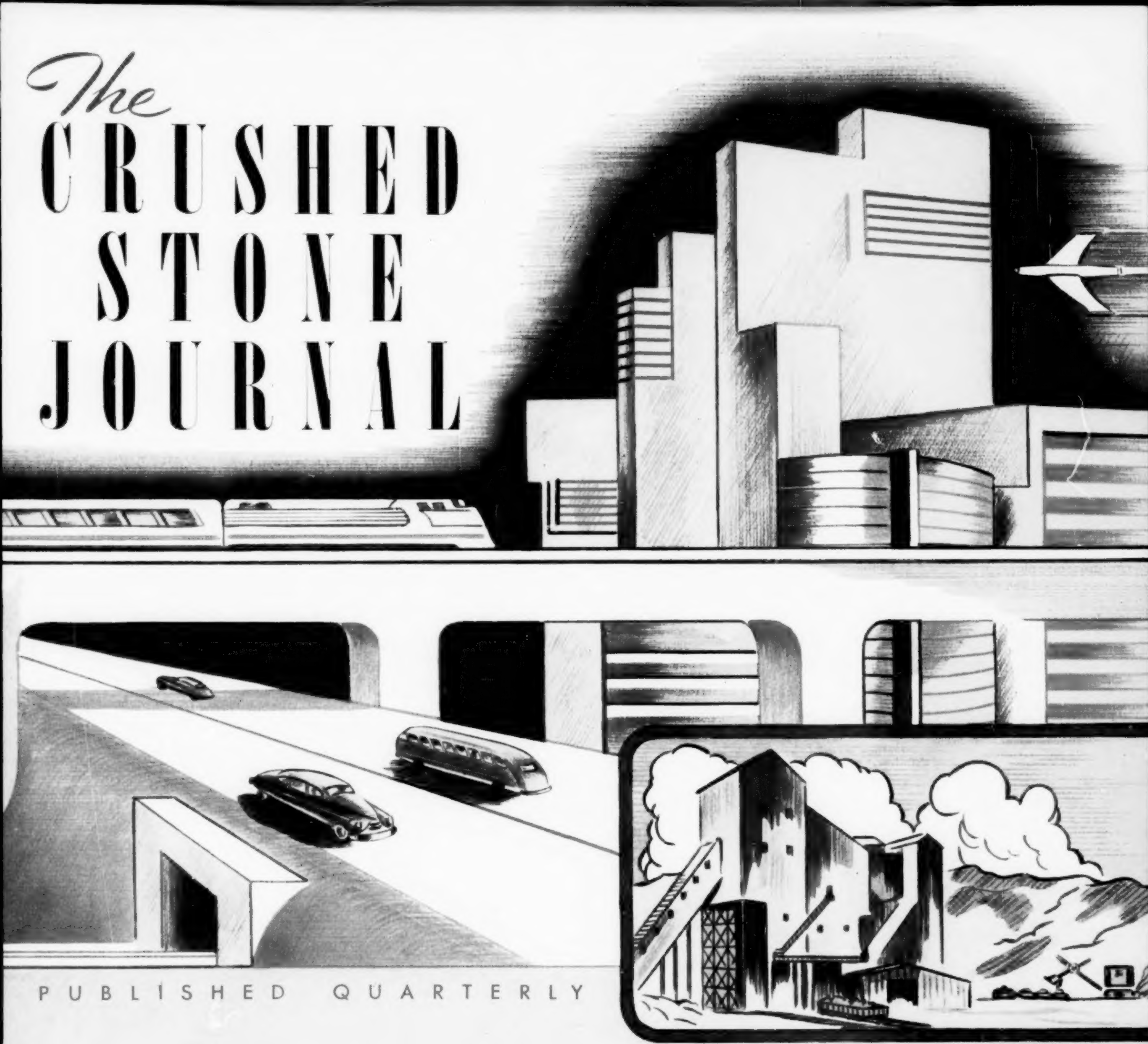
The CRUSHED STONE JOURNAL



PUBLISHED QUARTERLY

June 1957

In This Issue

OFFICIAL PUBLICATION · NATIONAL CRUSHED STONE ASSOCIATION

Technical Publications
of the
National Crushed Stone Association

STONE BRIEFS

ENGINEERING BULLETINS

•

Single copies of the above publications are available upon request.

The Crushed Stone Journal

Official Publication of the NATIONAL CRUSHED STONE ASSOCIATION

J. R. BOYD, Editor

Contents

41st ANNUAL CONVENTION

NATIONAL CRUSHED STONE ASSOCIATION
and
BIENNIAL EXPOSITION of the MANUFACTURERS DIVISION

★ ★ ★ ★ ★ ★

THE CONRAD HILTON • CHICAGO, ILLINOIS

FEBRUARY 17, 18, and 19, 1958

THE
CRUSHED STONE JOURNAL
WASHINGTON, D. C.

Vol. XXXII No. 2 PUBLISHED QUARTERLY JUNE 1957

Some Thoughts on Concrete Pavement Problems

By A. T. GOLDBECK
Engineering Consultant
National Crushed Stone Association
Washington, D. C.

THE following random thoughts have occurred as the results of a recent exceedingly interesting field inspection of concrete pavements made in company with a number of members of the Committee on Rigid Pavement Design of the Highway Research Board. Actually, the thoughts which follow were not raised during the inspection but have since occurred as the result of further thinking of the problem of concrete pavement design and of concrete pavement behavior.

Plastic Cracking

For the sake of adhering to some semblance of continuity, let's start at the beginning of construction of the pavement slab. The concrete is placed on the subgrade or, in more recent construction, on a granular sub-base and almost immediately there is a tendency for the mixing water to disappear, either by evaporation or by absorption. Hot weather, low humidity, wind, porous subgrade, and porous, absorbent aggregates are the active agents which make the concrete dry out rapidly, and when this happens, crazing or fine hair checking of the surface due to shrinkage appears or, in severe cases, large shrinkage cracks are formed, sometimes parallel to one another and at an angle with the sides of the pavement. (Figure 1) A porous subgrade with local roughnesses will accentuate this form of cracking because when the concrete shrinks it tends to move over the subgrade and this motion is resisted by the subgrade friction. Fresh concrete has practically no strength and of course even the slight tension generated by these friction forces will exceed the tensile strength of the concrete and a crack forms. The cure for this difficulty consists of making the subgrade as smooth as possible, sometimes by the use of a layer of damp sand and sometimes even waterproof paper is advisable. Also, and of even more importance, protection from the wind and

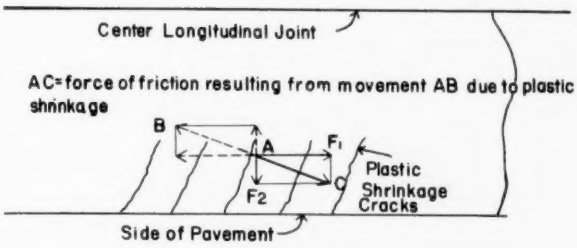


FIGURE 1
One Type of Plastic Shrinkage Cracks

sun should be given and the use of a water spray as soon as possible is a good precaution. Thus the disappearing mixing water will be re-supplied and the shrinkage will be minimized.

Thermal Cracking of Freshly Placed Concrete

Sometimes concrete placed near the end of the day will develop transverse cracking which will show up the next day rather close to the construction joint. This is due to the temperature falling at night; thus the slightly hardened concrete is caused to contract and this contraction is resisted by the subgrade friction and since the concrete has gained very little strength it is unable to resist the "drag" of the subgrade and enough tension is produced to crack the still very weak slab. When this becomes a troublesome problem, the surface of the concrete placed near the end of the day should be

covered with an insulating layer of straw or other heat insulating material so as to avoid an excessive decrease in temperature during the night.

Thermal Warping Stresses

When the slab hardens it begins to develop high stresses due not only to the wheel loads of traffic but also to the fact that every day there occurs a cycle of temperature changes—warming up under the hot sun and cooling at night. These cycles are rather rapid and since concrete is not a good conductor there is always a differential in temperature between the top and bottom of the slab of considerable magnitude. During the heat of the day the top surface becomes heated while the bottom next to the subgrade or sub-base changes very little. Hence the top expands and the bottom changes in length a relatively small amount. The slab humps up at the center and its weight tends to bend it down. Hence the top of the slab is compressed and the bottom is stretched or subjected to tensile bending stresses. At night the reverse is true. The top is cooler than the bottom and hence the ends, sides, and corners rise, sometimes under a sudden, severe drop in temperature. They tend to be bent down under their own weight and thus tension is produced at the top and compression at the bottom. The thicker the slab the more severe is this temperature differential and hence the greater is this so-called warping stress. Traffic loads tend to accentuate the effect of the warping stresses. Largely because of these temperature effects transverse cracks are formed. When no steel reinforcement is used, these cracks can become wide enough to admit water to the subgrade and if they are to be avoided it is good practice to build transverse joints into the pavement.

Influence of Coarse Aggregate on Warping of Pavement

The aggregate producer will be interested to know that the thermal coefficient of expansion of concrete differs widely and the coarse aggregate largely controls this expansion or contraction. Coarse aggregates have a wide range in thermal expansion varying from 0.000003 to 0.0000075. Limestones and traps generally have a low thermal coefficient and siliceous aggregates such as quartz and chert have a very high thermal coefficient. Also, aggregates vary a lot in their surface smoothness and the character of their fracture. Some fracture with a smooth, concoidal surface, others with a rough, precipitous surface which furnishes an excellent mechanical bond with the mortar. As a consequence, it is not impossible to find the transverse cracks in low thermal coefficient concrete very widely spaced, up to 100 or 200 ft apart; others with a high thermal coefficient as low as 15 ft apart. Probably the bond between coarse aggregate and mortar and perhaps other little understood phenomena also control the frequency of cracking.

Spacing of Contraction Joints in Plain Concrete Slabs

When building unreinforced pavements it is usual to space contraction joints from 15 to 25 ft apart to prevent objectionable intermediate cracks from forming, but when previous experience is favorable, even wider spacing is acceptable. The friction effect of the subgrade, although important, is minor compared with the warping effect of temperature differential between the top and bottom of the slab. Limestones, traps, and granites have an exceptionally good service behavior due to their low thermal effects and their favorable bond with the mortar.

When joints are used in plain unreinforced slabs they should not be expansion joints but rather contraction joints formed by installing planes of weakness which will cause the slab to crack at the desired locations. This plane may be a groove built into the slab or a transverse saw cut is made in the top surface to a depth of a few inches. When the slab cracks it will do so at these weakened planes and the cracks in the lower part of the slab will be irregular, generally following the surfaces of the aggregates.

Aggregate Interlock

Obviously, as long as the crack remains tightly closed, the aggregates form projections which fit into the adjoining slab and there is created a condition known as "aggregate interlock;" one slab is prevented from moving vertically with respect to its neighbor, and thereby the slabs are prevented from "faulting." Such a joint remains effective for transferring wheel loads from one slab to the other only as long as it remains tightly closed. A slight separation may destroy the aggregate interlock and due to heavy wheel loads the slabs might fault at the joint. Such a condition is readily detected by the

traveling public by the severe bumping as the wheels travel over the joint. This faulting in severe cases results in a lowering of the "far" side of the joint by as much as 3/8 to 1/2 in. The joint becomes a weak spot in the pavement and failure, especially on a poor subgrade, is imminent.

Strong Sub-base Beneficial

A pavement built in this manner requires an extra strong sub-base and no expansion joints should be used, for these permit the slabs to separate and lose their aggregate interlock. Under automobile traffic alone, plain slabs built on a strong sub-base, with contraction joints but without expansion joints, can be successful but it seems inadvisable to resort to this construction when heavy trucks are to be carried, for faulting at the joints has occurred too frequently. *A well graded stone sub-base makes an excellent support* built either as a graded aggregate or a macadam base in which case care must be taken to provide, on top, a smooth, thin course of sand or screenings so as to reduce the subgrade friction.

Reinforced Slabs

When reinforcing steel is used its purpose is not to prevent cracking, for this is impossible, but rather to hold the cracks tightly closed and thus prevent the infiltration of water. This construction involves the use of widely spaced transverse joints, either contraction or expansion joints and at such joints a means of carrying the load from one side of the joint to the other is provided. Steel dowels are most widely employed for this purpose, generally located at the center of the slab in a line across the pavement, spaced 12 in. apart, and varying from 3/4 to 1 1/4 in. in diameter. In one state, the sliding end of the dowel is protected with stainless steel to keep the dowel from "freezing" to the concrete due to rust.

Load Transfer Devices

Dowels are at present the best means of transferring load from one side of the joint to the other and thus make the adjoining slabs help to support one another. However, a dowel is by no means a perfect load transfer device. Dowels require almost perfect parallelism in their installation; they do rust and grab and in the course of time they do cause enlargement of the hole in the concrete on the sliding end, particularly near the joint. The reason for this is evident. The joint deflects under the action of passing wheel loads and thus the dowel tends to bend and slide with each passing load. Very large pressures are built up between the dowel and the concrete so that the sliding action now has considerable abrading effect. It is believed that thought on the proper design of a better load transfer device is badly needed and the slight additional expense needed to overcome the present deficiencies in the dowel would be negligible in comparison with the benefits to be derived. The difficulties are admitted.

Waterproofing of the Shoulder

Some years ago an investigation of concrete pavements built on an extremely plastic subgrade was made to determine the reasons for the formation of longitudinal cracks just a few feet from the sides of the concrete. The subgrade had great capacity for absorbing water and showed great volume change as the water content varied. Under the center of the pavement the change in moisture was negligible but near the shoulders a very considerable change took place. (Figure 2) In the wet season the shoulders were water-soaked and swollen; in the dry season, they became very dry and showed wide shrinkage cracks. Thus there was a very great volume change in the subgrade under the pavement near the shoulder but very little change near the center. Obviously, then, the sides

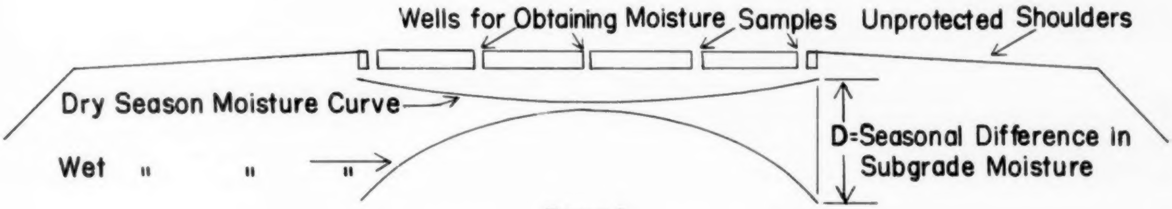


FIGURE 2
Seasonal Variation of Moisture Content in Subgrade

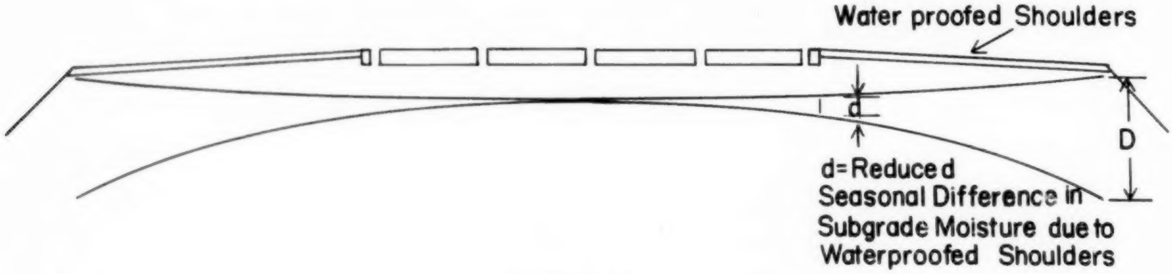


FIGURE 3
Improvement in Uniformity in Subgrade Moisture
Due to Waterproofing of Shoulders

of the road were heaved up in the wet season due to the swollen subgrade, but in the dry season they were left without any support whatever, due to the very great subgrade shrinkage. No wonder that longitudinal cracks developed.

Another effect must also be produced, especially in soils having low volume change; there must be a very wide range in support offered to the edge of the pavement slab but at the center this support remains practically constant. If the moisture content were to remain constant throughout its width, the slab would be supported in a uniform manner. If the shoulders were waterproofed by means of a suitable form of bituminous surface treatment, the zone of high moisture change would be transferred from the side of the slab out to the edge of the waterproofed shoulder. (Figure 3) The recent WASHO accelerated traffic tests showed definitely the great benefit of waterproofing the shoulders.

Another matter worth noting is that the joint between the side of the slab and the waterproofed shoulder should be kept sealed in the same manner as a transverse expansion joint is sealed, for it is just as important to keep the water out of this joint as from the expansion or contraction joint. More attention to improving the shoulder is needed, using a substantial load supporting and waterproof surface, for this is a relatively inexpensive way to increase the load carrying capacity of the pavement and it further gives extra traffic capacity to the pavement; it is an excellent safety measure.

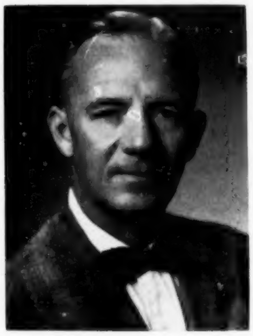
To the stone producer it should be evident that he has an opportunity to be of real service in improving the life, the load carrying capacity, and the safety of highways, not only of concrete, but of the bituminous concrete type also. It is urged that there be greater use of stone in—

a. The building of a really substantial sub-base under pavements

b. Concrete pavements, which as a whole should result in reducing temperature warping stresses and the frequency of transverse cracking

c. The building of substantial, waterproof shoulders which by actual test have shown their benefit in increasing the load carrying capacity of the pavement.

Howard M. Bixby Joins NCSA Staff As Field Engineer



Howard M. Bixby

THE National Crushed Stone Association is pleased to announce the appointment of Howard M. Bixby to the engineering staff as Field Engineer, to assume his duties on July 22. Mr. Bixby comes to the organization from the U. S. Bureau of Public Roads with a broad experience in materials and highway engineering. His most recent assignment was Regional Materials Engineer for Region 2, comprised of the States of Delaware, Maryland, Ohio, Pennsylvania, Virginia, West Virginia, and the District of Columbia.

A native of Nebraska, Mr. Bixby graduated from the University of Maryland College of Engineering in 1933. Following a short term of employment with the District of Columbia Department of Highways under the Federal Civil Works Administration Program in 1933 and 1934, he was an engineer with the Nebraska Department of Roads and Irrigation, with headquarters at Lincoln, Nebraska, until 1942.

As a reserve officer in the Corps of Engineers he went on active duty in 1942 and his service with the Corps of Engineers and the Ordnance Department included twenty-three months in the European Theater of Operations. Following World War II he was employed by the Bureau of Public Roads as Materials and Maintenance Engineer in Cheyenne, Wyoming, for six years.

In 1952 Mr. Bixby was transferred to San Jose, Costa Rica, as Regional Materials Engineer for the Inter-American Highway in Guatemala, San Salvador, Honduras, Nicaragua, Costa Rica, and Panama. He returned to the United States in 1955 with the Federal Bureau's Region 2 in Hagerstown, Maryland, which is his present home. Mr. Bixby is a registered professional engineer and a member of the American Society of Civil Engineers.

With Mrs. Bixby, his two daughters and one son, he plans to re-establish his home in the Washington suburban area.

We extend a hearty welcome to Mr. Bixby who will occupy the position vacated by J. E. Gray in 1956 when Mr. Gray was appointed Engineering Director.

Announcing . . . .

SEVENTH ENGINEERING CONFERENCE

ON

CRUSHED STONE AND ITS USES

to be given by the

NATIONAL CRUSHED STONE ASSOCIATION

OCTOBER 14, 15, 16, 1957

MAYFLOWER HOTEL, WASHINGTON, D. C.

Representatives of member companies, particularly those engaged in sales, and interested State and Federal Government Engineers are cordially invited to attend.

Details regarding the program will be announced in the near future through periodic releases. Drop us a note saying that you would like to attend this conference so that you may receive direct notices as the program develops.

NATIONAL CRUSHED STONE ASSOCIATION

1415 Elliot Place, N. W. · Washington 7, D. C.

The Skidding Resistance of Roads and the Requirements of Modern Traffic[1]

By CYRIL GEORGE GILES, B. Sc.
Road Research Laboratory
H. M. Department of Scientific and Industrial Research
London, England

As abstracted by J. E. GRAY
Engineering Director
National Crushed Stone Association
Washington, D. C.

Introduction

EVEN with improvements in road surfaces, the present trend is an increase in proportion of skidding accidents on wet roads due primarily to increased performance and speed of the modern automobile. However, accident studies show a marked tendency for skidding accidents in wet weather to cluster at comparatively few points on the heaviest traveled roads. Measurements confirm that the skid resistance at these sites is lower than at other places on the same road. While slippery surfaces can be measured and it would appear to be desirable to establish standards for reference in comparing road surfaces, many factors intervene which complicate the problem to the extent that it is unlikely that it will ever be possible to lay down simple standards for skidding resistance which will always be realistic. Skid resistance under wet conditions depends upon speed and vehicles travel at a wide range of speeds. Vehicle characteristics are important and vehicles have a wide range of characteristics which includes varying conditions of maintenance. Skidding should not occur under skillful driving; yet, drivers are of extremely varying skill and each is likely to meet all kinds of emergencies because of the action of others. Road layout, by influencing the kind of maneuvers drivers are likely to make, is important in determining the liability of vehicles to skid. Thus the necessary skid resistance for tangents and easy curves is different from the requirements for steep grades, sharp curves, and turns.

1 Excerpt from the Proceedings of the Institution of Civil Engineers, Vol. 6, pp. 216-249, February 1957. Published through courtesy of The Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, England and of the Director of Road Research.

Skidding Resistance and Acceleration: The Fundamental Relation

When a vehicle is moving, each element of tire in contact with the surface is momentarily at rest and this stationary contact area beneath each rolling wheel forms the essential link between car and road surface by which the position of the car is defined. The vehicle is steered, braked, and driven by exerting forces on these contact areas in the plane of the road surface. The friction between the tire and road opposes these forces and normally the friction is great enough to resist their action without sliding or skidding, so the vehicle is fully under the driver's control.

When the vehicle is moving in any direction with all its wheels sliding, the acceleration of the vehicle expressed in terms of g, acceleration due to gravity, is numerically equal to the skidding resistance of the surface. This is the basic relation in considering skid-resistance requirements of any combination of road, vehicle speed, and so on, but it is important to realize that it will give only the minimum value assuming proportional distribution of the total load to each wheel. In practice, this ideal distribution of weight is not obtained because of the varying effects of weight transfer in braking, cornering, and acceleration. If brakes and steering are out of adjustment, or the distribution of braking effort at the wheels is very uneven, the minimum skidding resistance required for a given maneuver will be increased. It is known that about 30 per cent of cars on the road in Great Britain have little or no braking on one or more wheels. Difficulties can arise with empty trucks, where braking the rear wheels may cause them to lock and skid, allowing the rear to swing violently sideways at quite a low over-all deceleration. Serious brake unbalance can have similar effects. In all these circumstances, the coefficients necessary to prevent skidding are likely to be much higher than the values indicated from the deceleration involved.

Standards Required by the Modern Vehicle

There is little doubt that the improved performance of modern vehicles is an important factor in the present trend toward an increase in accidents involving skidding. The pertinent improvements in the modern car over its predecessors are the ease with which it can be driven at high speeds, the independent front end suspension system, increase in engine power, the shifting of weight which has reduced the proportion on the rear wheels. These changes necessitate increased coefficients between tire and road to prevent the rear wheels spinning and skidding when the car is accelerated.

Braking Requirements

The provision of sufficiently high skid resistance to meet the maximum performance of the modern car when braking in wet conditions presents a virtually insoluble problem for the highway engineer. To attain the shortest braking distances of which vehicles are capable, that is, with wheels locked on dry surfaces, a maximum deceleration approaching 1.0 g is required and for this to be possible a coefficient approaching 1.0 is needed. In testing American cars at speeds up to 90 mph Norman has reported the attainment of decelerations of about 0.6 g on dry surfaces. Thus, in braking performance, the modern car is certainly able to utilize the highest coefficient likely to be obtained and even these are not likely to prevent wheels from locking and skidding when the maximum braking effort is applied. In normal driving, minimum coefficients of about 0.4 are certainly likely to be necessary if skidding is not to occur more frequently than once in every 500 applications of the brake.

Measurement of Skid Resistance

In considering the requirements for skid resistance, the coefficient of friction has been determined in most cases by the sideway-force method under carefully standardized conditions and under wet conditions the road surface is of primary importance.

Variations in Skidding Resistance

Under the influence of traffic and weather the surface texture changes, so the skidding resistance of roads can vary in a manner by no means easy to predict. Thus, as surfaces polish and become smoother, skidding resistance tends to diminish, while, if there is any disintegration, even on a microscopic scale, skidding resistance tends to improve. Wet road surfaces are very liable to exhibit more or less regular "seasonal changes" in skidding resistance giving higher values in winter than in summer. In Great Britain these seasonal changes in slipperiness have a marked effect on the frequency of skidding accidents; the over-all percentage of wet road skidding accidents has been three times higher in summer than in winter. However, roads with intense traffic at all times of the year tended to have small seasonal changes in skidding resistance.

Risk of Skidding Accidents

Of 93 skidding accidents studied, 45 took place on bends, 32 on gradients, 13 at junctions, and 31 on straight roads, mainly as vehicles were overtaking. As anticipated from consideration of vehicle characteristics and driving methods, conditions become critical as far as skidding accidents are concerned with values of coefficient of about 0.4. While few lengths of road had this sideway force coefficient, it was at those sites which were associated with some difficult feature such as turnarounds, bends, or grades where repeated skidding accidents occurred. From the point of view of safety it is those "skidding accident sites," where the proportion of skidding accidents in wet weather is significantly higher than that expected by chance which are of special importance, since at these places some factor connected with the road or its surface is responsible. The highway engineer aims to prevent such sites from occurring, or if they should occur, to detect and remedy them as quickly as possible.

Speed and Requirements for Skidding Resistance

With effective coefficients of about 0.4 or less, there is a very large increase in the risk of skidding. Normally in considering the skidding resistance of surfaces, it is customary to think in terms of the sideway force coefficient at 30 mph. It is important, therefore, to consider how the coefficient at this speed may have to be increased to insure a coefficient of about 0.4 at the speed of the traffic using any particular section of the road. On the basis of the measurements so far made, it is possible only to suggest tentative limits within which coefficients at 30 mph should lie to insure a coefficient of 0.4 at various speeds. Thus, the coefficient at 30 mph must

probably be on the average 0.46, 0.55, 0.61, 0.64 to insure a coefficient of 0.4 at speeds in mph of 40, 60, 80, 100.

In general, speed has the greatest effect on coefficients in the case of the smooth or fine-grained type of surface. Often at speeds below about 15 mph such surfaces will give appreciably higher values of coefficient than surfaces of the rough, coarse-textured type having the same performance at 30 mph. Where conditions insure that speeds are low, such as at turnarounds, the approaches to some traffic lights, or on gradients in busy city areas, it is therefore sometimes possible to bring about a useful reduction of skidding accidents by substituting a fine-textured surface giving higher coefficients at lower speeds for an existing polished surface of the rough, coarse-textured type.

There may be some advantage where traffic speeds are low in using the more close-textured types of surfacing to insure the most satisfactory values of coefficient at low speeds. On roads with fast traffic, on the other hand, because of their better characteristics at higher speeds, it may well be that surfaces of the rough, coarse-textured type should be preferred.

Suggested Standards of Skidding Resistance

From the results considered, standards of skidding resistance represented by different values of sideway force coefficients within this range at 30 mph may be summarized as follows:

1. Coefficients of 0.6 and greater—a good resistance to skidding fulfilling requirements even for fast traffic.

2. Coefficients of 0.5-0.6—generally satisfactory, meeting most requirements except for the most difficult conditions as represented by a curve on a road with very fast traffic.

3. Coefficients of 0.4-0.5—satisfactory, except for conditions at critical sites such as curves, grades, or junctions.

4. Coefficients below 0.4—potentially slippery; with coefficients below this figure, skidding accidents may occur even on straight roads.

Meeting These Suggested Requirements

On wet roads, slippery conditions arise through the lubricating action of the water film. To insure a high resistance to skidding, this film, typically about 0.020 in. thick, must be displaced and penetrated by the projections in the road surface rapidly enough to insure that as the vehicle travels along a large proportion of the load on the tire is supported on parts of the road surface which have made direct contact with the tire tread. A rough, coarse-textured surface or a smooth surface with the use of patterned tires assist in this by making it easier for the water film to escape from the zone of contact. This alone is not sufficient to insure a high skidding resistance, however, since the film thickness of about 0.001 in. the rate of expulsion of the film becomes comparatively slow. At this stage the harshness of the surface texture as determined by the sharpness of the peaks and ridges composing the surface is the decisive factor. When sharp projections are forced into a material such as rubber, intense localized pressures of several thousands of pounds per square inch are set up on the peaks. These intense pressures are needed to expel the last traces of the water film. Where the edges are smooth and polished, the effect is missing and tests have shown that on rough, coarse-textured surfaces of this type, a water film of even about 0.001 in. thick is sufficient to give slippery conditions.

With any type of surfacing, a good resistance to skidding is obtained first by insuring that the composition is such that the texture of the right kind will be presented to the tire, and secondly, that this necessary harsh texture is maintained during the life of the surfacing under the traffic and weather conditions experienced. It is meeting the second requirement despite the polishing action of traffic which seems primarily responsible for most present difficulties of slippery roads. Aggregates appear to differ in their ability to resist polishing, but some appear able to retain sufficient harshness to insure a good skidding resistance, even under extremely heavy conditions of traffic. It is the aggregates which are able to retain their harshness under such heavy traffic conditions that need to be used for the most difficult sites on busy roads. As the site conditions become less severe, the choice of materials becomes much wider and on the least busy roads very many aggregates can be relied upon to give a high resistance to skidding.

For all modern materials, there is some range of traffic load conditions under which they may give satisfactory or good values of coefficient over a useful period and it is suggested that conditions surveys carried out more extensively would go a long way

(*Continued on Page 15*)

The Accident Makers[1]

By GERALD GORDON, M.D.
E. I. Du Pont de Nemours & Co.
Wilmington, Del.

FOR years one group of Du Pont maintenance and construction workers had posted probably the worst safety record in the entire Company. Supervisors shook their heads sadly at annual performance reviews, claiming they did everything but think for their men to protect them from injury. Year after year they expressed the hope that the "bad luck" would stop.

It did not. Finally, the department management called in the superintendent and told him he must accept direct responsibility for the safety of his men. Supervisors were warned that their performance was unsatisfactory so long as they continued to tolerate unsafe acts. No changes were made in type of work, personnel or safety procedures. Yet during the next three years, this same group created what might well be a world's safety record for construction and maintenance work.

Why the abrupt drop in accidents? The answer, although simple, is startling to many people: Accidents don't just happen; they are caused. Moreover, in most cases the cause is something the victim himself did or didn't do. The accidents decrease when the men responsible for them are made to work safely and productively.

Industry spends prodigious amounts of money and effort to provide safe working conditions. Du Pont's efforts have 12 times won the National Safety Council's highest award. Yet even in a company where the injury record is about 18 times better than that of industry as a whole, workers still hurt themselves unnecessarily.

Our studies have revealed a small group of individuals around whom occupational injuries seem to cluster in disproportionate numbers. Obviously there is something more than hard luck plaguing a man whose career shows a long series of injuries. What's back of his troubles? The answer is that the accident maker is suffering from a form of mental illness so widespread that it may be found to some degree in most of us. Because it is so universal, we find it difficult to see in others, and all but impossible to see in ourselves.

It is the failure of the employe as a whole person that is the core of his problem. He tends to evade the rules, both of working and of living. A medical investigator who has visited the homes of accident victims reports that he frequently finds social and economic difficulties. In most cases, the potential accident victim has a long service record and is well trained for his job. But all too often he's a victim of his own bottled-up emotions, which he turns against himself. His plight may be further complicated by childhood experiences that taught him to gain attention and sympathy by being sick or hurting himself rather than by good behavior.

Sometimes these people are called accident-prone, but I dislike this term because it implies their weakness is inborn and can't be corrected. Actually they can be helped fairly easily if they are discovered early enough and something is done to help them.

Direct psychiatric work is one way, but this is obviously not always possible or desirable. A second approach, however, proves highly effective. This, as I mentioned earlier, involves requiring employes to follow safety rules and develop sound work habits. In my opinion, the fact that a worker violates a safety rule is more important than *why* he violates it. Pampering the emotionally disturbed individual only serves to increase his demands and, at the same time, aggravates the severity of his illness.

If a supervisor openly and honestly exercises his authority to obtain good performance, he is helping both the employe and the company for which they both work. On the other hand, a supervisor who evades responsibility for the safety of his men becomes mentally ill himself and spreads this illness to others.

When the safety, attendance and medical records of an accident maker are compared, the correlation

(Continued on Page 15)

1 Reprinted from Du Pont Magazine, February-March 1957, through the courtesy of and with permission from E. I. du Pont de Nemours & Co.

Crushed and Broken Stone in 1955 *

By WALLACE W. KEY
NAN C. JENSEN

Under the Supervision of G. W. Josephson, Chief
Construction and Chemical Materials Branch
Minerals Division, U. S. Bureau of Mines
Washington, D. C.

OUTPUT of crushed and broken stone in 1955 as reported to the Bureau of Mines, United States Department of the Interior, reached the new record of 468,140,945 tons valued at $632,954,944, compared with 409 million tons at $546 million in the previous year. Included in the 1955 total is stone used for concrete aggregate, roadstone, cement, lime, metallurgical use (flux), railroad ballast, refractory stone, agricultural limestone, abrasives, riprap, and various other applications. Stone used as asphaltic stone and slate used for granules and flour are not included in this total. There were tonnage gains in virtually all classifications in 1955. Prices remained low in spite of more exacting specifications and rising costs of labor and equipment. The low selling price maintained by the crushed stone industry in 1955 was attributed to keen competition, more advanced technology, and increased influx of portable operations.

Crushed and broken stone used for railroad ballast (3 per cent of the total output in 1955) increased 5 per cent in quantity and 13 per cent in value, compared with the 1954 totals. Eighty-seven per cent of the 256,454,230 short tons used for concrete and roadstone was produced by commercial operators and 13 per cent by Government agencies.

Portland natural cement which took 18 per cent of the total crushed and broken stone in 1955 increased 14 per cent in quantity and 19 per cent in value over 1954 totals. Limestone for agricultural

* MINERAL MARKET REPORT MMS. NO. 2620, April 18, 1957

CRUSHED AND BROKEN STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES [1] 1954-55, BY PRINCIPAL USES

Use	1954			1955		
	Short Tons	Value		Short Tons	Value	
		Total	Average		Total	Average
Concrete and roadstone	216,614,445	$289,441,803	$1.34	256,454,230	$338,593,129	$1.32
Railroad ballast	15,172,606	14,871,002	.98	15,870,781	16,757,595	1.06
Portland and natural cement [2]	[3] 73,694,015	[3] 75,591,872	[3] 1.03	84,211,426	89,671,896	1.06
Furnace flux (limestone)	33,161,736	40,933,952	1.23	40,068,165	52,905,898	1.32
Agricultural limestone	18,247,121	30,199,337	1.66	18,360,040	29,455,066	1.60
Lime and dead-burned dolomite	[3] 15,065,389	[3] 19,982,152	[3] 1.33	15,615,905	20,668,064	1.32
Riprap	7,642,332	10,979,042	1.44	10,285,771	13,680,155	1.33
Alkali works	5,329,939	4,659,840	.87	5,753,468	6,280,552	1.09
Refractory [4]	1,529,570	5,923,312	3.87	1,941,271	6,588,256	3.39
Asphalt filler	1,007,358	2,907,688	2.89	1,405,477	4,366,991	3.11
Glass factories	[3] 1,046,782	[3] 3,116,196	[3] 2.98	1,070,954	2,905,061	2.71
Calcium carbide works	709,453	611,565	.86	719,428	621,536	.86
Sugar factories	788,210	2,141,351	2.72	661,004	1,624,636	2.46
Paper mills	484,372	1,150,428	2.38	518,381	1,208,742	2.33
Other uses	[3] 18,198,558	[3] 43,791,340	[3] 2.41	15,204,644	47,627,367	3.13
Total	[3] 408,691,886	[3] 546,300,880	1.34	468,140,945	632,954,944	1.35

[1] Includes Territories of the United States, possessions, and other areas administered by the United States
[2] Limestone, cement rock, and oyster shells
[3] Revised figure
[4] Ganister and dolomite

STONE [1] SOLD OR USED BY PRODUCERS IN THE UNITED STATES, 1954-55, BY STATES

State	1954		1955	
	Short Tons	Value	Short Tons	Value
Alabama	7,393,530	$11,608,937	8,269,355	$11,867,191
Arizona	1,205,452	1,914,315	1,600,939	2,328,566
Arkansas	4,604,067	5,929,638	6,176,313	8,025,634
California	23,303,756	37,541,114	24,726,276	37,893,386
Colorado	1,804,004	2,112,093	2,149,019	3,508,053
Connecticut	[2] 2,829,198	[2] 4,269,430	[2] 3,641,992	[2] 5,451,550
Delaware	(3)	(3)	78,791	227,450
Florida	[2] 14,225,356	[2] 16,832,066	[2] 17,027,967	[2] 22,966,008
Georgia	8,057,600	21,384,227	[2] 7,488,452	[2] 14,249,830
Idaho	2,329,005	3,012,613	[2] 1,248,290	[2] 1,515,376
Illinois	26,407,088	31,134,135	28,865,724	35,621,394
Indiana	11,181,838	27,460,119	14,124,406	34,679,589
Iowa	13,240,087	16,388,141	15,705,412	18,555,176
Kansas	10,377,008	12,941,822	[2] 12,470,616	[2] 15,887,269
Kentucky	10,129,725	13,285,786	11,933,899	15,579,312
Louisiana	(3)	(3)	1,243,486	1,662,715
Maine	1,023,709	2,355,385	1,192,361	2,542,228
Maryland	5,064,526	8,265,521	[2] 5,342,968	[2] 8,800,044
Massachusetts	2,942,435	9,039,590	4,128,003	11,381,164
Michigan	27,758,443	21,904,517	33,635,612	28,908,784
Minnesota	[2] 2,629,456	[2] 7,485,291	[2] 3,004,521	[2] 7,042,840
Mississippi	[4] 181,418	[4] 181,418	572,816	572,816
Missouri	18,615,739	24,695,110	[2] 22,368,768	[2] 29,580,414
Montana	1,319,829	1,385,239	1,273,600	1,199,619
Nebraska	2,660,170	3,511,494	3,081,247	4,177,361
Nevada	1,832,781	2,010,592	1,611,942	2,608,900
New Hampshire	72,486	473,298	(3)	(3)
New Jersey	5,772,200	12,109,950	[2] 8,357,599	[2] 17,527,890
New Mexico	771,630	714,037	1,573,441	1,546,665
New York	19,410,121	31,425,701	22,812,222	37,919,063
North Carolina	10,133,728	15,625,331	10,903,366	16,532,910
North Dakota	1,419	3,784	77,366	80,560
Ohio	32,626,737	47,802,169	33,272,567	49,841,246
Oklahoma	[2] 9,238,811	[2] 9,146,995	10,933,355	12,295,274
Oregon	5,872,353	8,617,795	7,741,937	9,417,834
Pennsylvania	40,521,756	61,193,419	44,437,623	70,056,080
Rhode Island	(3)	(3)	(3)	(3)
South Carolina	[2] 2,861,953	[2] 4,233,270	3,455,388	4,920,697
South Dakota	1,614,818	4,928,855	2,262,246	5,679,444
Tennessee	14,040,187	22,046,016	16,389,665	24,996,608
Texas	[2,4] 25,840,338	[2,4] 29,343,684	[2] 27,234,619	[2] 32,872,552
Utah	1,127,461	1,545,841	1,925,867	2,650,480
Vermont	436,870	8,178,389	581,749	11,061,196
Virginia	10,893,972	[4] 18,137,501	11,965,890	19,869,675
Washington	5,366,890	9,526,534	6,593,212	10,579,631
West Virginia	7,314,934	11,743,440	5,898,585	9,714,168
Wisconsin	8,289,373	16,187,738	[2] 12,180,452	[2] 18,843,272
Wyoming	1,616,015	1,665,302	1,303,399	2,033,800
Alaska	283,734	465,423	265,740	289,589
American Samoa	57,600	15,000	9,011	3,948
Canton Island	2,600	5,000	500	1,500
Guam	842,660	2,275,182	1,241,466	3,351,958
Hawaii	[6] 1,483,027	[6] 2,990,632	1,414,304	2,884,354
Johnston Island	98	300	12,090	32,550
Midway Island	490	1,500	......	......
Panama Canal Zone	187,446	245,170	169,485	239,280
Puerto Rico	[4,6] 1,751,996	[4,6] 2,492,827	1,783,910	2,515,760
Virgin Islands	3,939	17,134	875	4,900
Wake Island	780	1,300	1,000	3,000
Undistributed	[4] 1,519,527	[4] 3,591,071	2,930,469	15,078,754
Total [5]	[4] 411,074,169	[4] 613,398,181	470,692,173	709,677,307

[1] Includes: 1954—2,382,283 short tons of dimension stone valued at $67,097,301; 1955—2,551,228 short tons, $76,722,363
[2] To avoid disclosing confidential information certain state totals are incomplete, the portion not included being combined with "Undistributed"
[3] Included with "Undistributed"
[4] Revised figure
[5] Includes stone used for abrasives and in making cement and lime, and oyster shells for various uses
[6] Certain territory or area totals are incomplete, the portion not included being combined with "Undistributed"

CRUSHED STONE SOLD OR USED IN THE UNITED STATES[1] IN 1955, BY METHODS OF TRANSPORTATION

Method of Transportation	Commercial operations		Commercial and noncommercial[2] Operations	
	Short Tons	Per cent of Total	Short Tons	Per cent of Total
Truck	218,099,884	51	256,062,270	55
Rail	88,499,463	21	88,499,463	19
Waterway	48,491,274	11	48,491,274	10
Unspecified	75,087,938	17	75,087,938	16
Total	430,178,559	100	468,140,945	100

[1] Includes Territories of the United States, possessions, and other areas administered by the United States. Includes transportation of 107,923,981 tons of stone used in making cement and lime and oyster shells for various uses, as follows: By truck, 34,969,987 tons; rail, 7,042,018; waterway, 14,067,320; and unspecified methods, 51,844,656

[2] Entire output of noncommercial operations assumed to be moved by truck

purposes (4 per cent of the total tonnage) increased slightly in tonnage but decreased in value compared with the previous year. Furnace flux increased 21 per cent in tonnage and 29 per cent in value. Other uses consumed 3 per cent of the total of 15,205,000 short tons valued at $47,627,000.

In 1955, limestone, including dolomite, constituted 77 per cent of all crushed and broken stone sold and was quarried in 44 states and 2 territories.

The following tables present the salient statistics of the crushed and broken stone industries for 1954 and 1955.

LIMESTONE AND DOLOMITE (CRUSHED AND BROKEN STONE) SOLD OR USED BY PRODUCERS IN THE UNITED STATES,[1] 1954-55, BY USES

Use	1954		1955	
	Short tons	Value	Short tons	Value
Riprap	3,758,881	$4,644,040	5,259,382	$6,422,042
Fluxing stone	33,161,736	40,933,952	40,068,165	52,905,898
Concrete and roadstone	153,680,776	199,063,091	179,316,292	228,681,053
Railroad ballast	6,638,632	7,601,201	6,591,164	7,618,571
Agriculture	18,247,121	30,199,337	18,360,040	29,455,066
Alkali works	5,329,939	4,659,840	5,753,468	6,280,552
Calcium carbide works	709,453	611,565	719,428	621,536
Cement—Portland and natural	[2] 71,254,166	[2] 72,440,765	79,999,936	84,357,505
Coal-mine dusting	353,483	1,466,601	499,398	2,206,222
Filler (not whiting substitute):				
Asphalt	1,007,358	2,907,688	1,405,477	4,366,991
Fertilizer	433,590	865,122	449,902	850,645
Other	557,250	2,032,445	762,076	2,605,959
Filter beds	108,089	177,815	136,050	204,472
Glass factories	802,808	2,105,351	848,799	2,304,530
Lime and dead-burned dolomite	14,594,489	19,092,152	14,802,701	19,974,225
Limestone sand	1,466,842	1,832,621	741,854	924,377
Limestone whiting [3]	536,847	3,774,614	498,375	4,268,213
Magnesia works (dolomite) [4]	150,181	376,812	103,951	311,853
Mineral food	457,199	2,785,076	473,689	2,751,042
Mineral (rock) wool	48,859	167,734	19,386	46,181
Paper mills	484,372	1,150,428	518,381	1,208,742
Poultry grit	92,512	754,832	119,303	780,394
Refractory (dolomite)	645,175	1,008,492	1,059,901	1,271,732
Road base	1,908,854	1,634,578	889,308	1,271,684
Sugar factories	788,210	2,141,351	661,004	1,624,636
Other uses [5]	1,100,035	3,478,255	646,195	1,911,918
Use unspecified	1,628,991	1,735,843	1,492,605	1,471,663
Total	[2] 319,945,848	[2] 409,641,601	362,196,230	466,697,702

[1] Includes Hawaii and Puerto Rico

[2] Revised figure

[3] Includes stone for filler for calcimine, caulking compounds, ceramics, chewing gum, explosives, floor coverings, foundry compounds, glue, grease, insecticides, leather goods, paint, paper, phonograph records, picture-frame moldings, plastics, pottery, putty, roofing, rubber, toothpaste, wire coating, and unspecified uses. Excludes limestone whiting made by companies from purchased stone

[4] Includes stone for refractory magnesia

[5] Includes stone for acid neutralization, carbon dioxide, chemicals (unspecified), concrete blocks and pipes, dyes, electric products, fill material, litter and barn snow, oilwell drilling, patching plaster, rayons, rice milling, roofing granules, silicones, spalls, stucco, terrazzo, artificial stone, target sheets, and water treatment

CRUSHED AND BROKEN STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES [1] IN 1955, BY KINDS AND PRINCIPAL USES

Kind of Stone	Concrete and roadstone		Railroad ballast		Riprap		Agriculture	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Granite	21,189,435	$29,506,962	2,514,121	$2,808,019	493,218	$826,733	...	...
Basalt [2]	31,183,022	47,518,197	2,278,182	3,115,828	1,866,701	2,816,650	...	...
Marble	(3)	(3)	...	...	...	...	(3)	(3)
Limestone	179,316,292	228,681,053	6,591,164	7,618,571	5,259,382	6,422,042	18,360,040	$29,455,066
Oyster shells	5,750,728	8,164,979	...	...	...	...	...	...
Sandstone, quartz, and quartzite	7,821,075	10,665,446	723,012	870,394	1,313,490	1,958,896	...	...
Miscellaneous [4]	11,193,678	14,056,492	3,764,302	2,344,783	1,352,980	1,655,834	...	...
Total	256,454,230	338,593,129	15,870,781	13,757,595	10,285,771	13,680,155	18,360,040	29,455,066

Kind of Stone	Fluxing stone		Refractory stone		Other uses		Total	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Granite	...	...	...	...	1,265,878	$2,667,762	25,462,652	$35,809,476
Basalt [2]	...	...	...	...	463,016	3,613,010	35,790,921	57,063,685
Marble	...	...	...	...	976,150	7,251,309	976,150	7,251,309
Limestone	40,068,165	$52,905,898	1,059,901	$1,271,732	111,541,286	140,343,340	362,196,230	466,697,702
Oyster shells	...	...	...	...	7,370,616	11,165,566	13,121,344	19,330,545
Sandstone, quartz, and quartzite	(3)	(3)	881,370	5,316,524	2,203,074	8,092,816	12,942,021	26,904,076
Miscellaneous [4]	...	...	...	...	1,340,667	1,841,042	17,651,627	19,898,151
Total	40,068,165	52,905,898	1,941,271	6,588,256	125,160,687	174,974,845	468,140,945	632,954,944

[1] Includes Territories of the United States, possessions, and other areas administered by the United States
[2] Includes gabbro, diorite, and other dark igneous rocks commercially classified as traprock
[3] A small quantity included with "Other uses"
[4] Includes conglomerates, argillite, various light-color volcanic rocks, schists, serpentine, flint, and chats

The Accident Makers

(Continued from Page 11)

may be amazingly close. We had the performance of all the workers in one plant checked over a five-year period. Analysis showed a persistent, almost straight-line correlation between the number of visits to the dispensary for incidental complaints and the number of injuries suffered by the same individuals. Such persons also are likely to have more minor ailments and more trouble getting along with their supervisor and fellow employes, other studies show.

I have tried to point out an existing industrial problem and suggest one thing that can be done to correct it. More studies are needed before we can consider this area satisfactorily explored. It is already apparent, however, that we can do much to improve the safety performance and mental health of the accident makers by requiring them to meet the job responsibilities of normal people.

The Skidding Resistance of Roads and the Requirements of Modern Traffic

(Continued from Page 10)

toward guiding highway engineers to the range of conditions under which different materials available can be employed. In any case, recognizing that conditions at some sites may mean that a particular material is unsuitable, it cannot perhaps be too strongly emphasized that the sites where skidding is a serious problem are very largely confined to the difficult places on the busy roads. While for these special attention to the choice of materials, and even frequent surface treatment, may be required, there are of course a great many miles of road where it is clear that existing methods and materials are proving perfectly satisfactory.

The complete paper can be obtained from

The Institution of Civil Engineers
Great George Street, Westminster, London, S.W.1

Manufacturers Division
National Crushed Stone Association

•

These associate members are morally and financially aiding the Association in its efforts to protect and advance the interests of the crushed stone industry. Please give them favorable consideration whenever possible.

•

Allis-Chalmers Mfg. Co.
Milwaukee 1, Wis.
Crushing, Screening, Washing, Grinding, Cement Machinery; Motors; Texrope Drives; Centrifugal Pumps; Air Compressors; Hauling Equipment; Engines; Tractors

American Cyanamid Co.
Explosives Department
30 Rockefeller Plaza, New York 20, N. Y.
Explosives and Blasting Supplies

American Manganese Steel Division
American Brake Shoe Co.
155 North Wacker Drive, Chicago 6, Ill.
Manganese and Alloy Steel Castings, Power Shovel Dippers, Material Handling Pumps, Reclamation and Hard-Facing Welding Materials, Automatic and Semi-Automatic Welding Machines

American Pulverizer Co.
1249 Macklind Ave., St. Louis 10, Mo.
Manufacturers of Ring Crushers and Hammermills for Primary and Secondary Crushing and Laboratory Sizes

American Steel & Wire Division
United States Steel Corp.
Rockefeller Bldg., 614 Superior Ave., N. W., Cleveland 13, Ohio
Wire Rope, Aerial Wire Rope Tramways, Electrical Wires and Cables, Welded Wire Fabric, Concrete Reinforcing, Wire Nails, Fencing, Netting

Aquadyne Corp.
89 Terminal Ave., Clark, N. J.
Dust Control Systems, Truck Bed Separating Agent

Atlas Powder Co.
Wilmington 99, Del.
Industrial Explosives and Blasting Supplies

Bacon-Greene & Milroy
29 Washington Ave., Hamden 14, Conn.
"Farrel-Bacon" Jaw Crushers for Primary and Secondary Operations, Conveyors, Elevators, Rolls, Screens

Baldwin-Lima-Hamilton Corp.
Construction Equipment Division
South Main St., Lima, Ohio
Power Shovels, Draglines, Cranes, Bins, Conveyors and Idlers, Crushers and Pulverizers, Feeders, Plants—Crushing and Portable, Washing Equipment, Asphalt Plants, Dust Control Equipment, Roadpacker

Barber-Greene Co.
400 North Highland Ave., Aurora, Ill.
Portable and Permanent Belt Conveyors, Belt Conveyor Idlers, Bucket Loaders, Asphalt Mixing Plants and Finishers, Bucket Elevators, Screens

Birdsboro-Buchanan Crusher Dept.
Birdsboro Steel Foundry and Machine Co.
1941 Furnace St., Birdsboro, Pa.
Primary and Secondary Crushers and Rolls

Boston Woven Hose & Rubber Co.
Boston 3, Mass.
Conveyor, Elevator, and Transmission Belts, V-Belts; Sand Blast, Water, Steam, Air, Suction Hoses

Brunner & Lay Rock Bit of Asheville, Inc.
P. O. Box 5235, Asheville, N. C.
Tungsten Carbide Detachable Bits, "Rock Bit" Drill Steel Inlaid with Tungsten Carbide, Carbon Hollow Drill Steel, Alloy Hollow Drill Steel

Bucyrus-Erie Co.
South Milwaukee, Wis.
Excavating, Drilling, and Material Handling Equipment

Canadian Industries Ltd.
P. O. Box 10, Montreal, Que., Canada
Commercial Explosives and Blasting Accessories

Cape Ann Anchor & Forge Co.
P. O. Box 360, Gloucester, Mass.
"Cape Ann" Forged Steel Drop Balls

Caterpillar Tractor Co.
Peoria 8, Ill.
Track-Type Tractors, Bulldozers, Earthmoving Scrapers, Motor Graders, Heavy-Duty Off-Road Hauling Units, Diesel Engines, Diesel Electric Generating Sets, Front End Shovels, Wheel-Type Tractors

Manufacturers Division — National Crushed Stone Association
(continued)

Chain Belt Co.
P. O. Box 2022, Milwaukee 1, Wis.
Rex Conveyors, Elevators, Feeders, Idlers, Elevator Buckets, Drive and Conveyor Chains, Sprockets, Bearings, Pillow Blocks, Power Transmission Equipment, Portable Self-Priming Pumps, Concrete Mixers, Iron Castings, Clutches

Clark Equipment Co.
Construction Machinery Division
P. O. Box 599, Benton Harbor, Mich.
Tractor Shovels; Tractor Dozers; Tractor Scrapers; Truck and Crawler Excavator-Cranes

Continental Gin Co.
Industrial Division
4500 Fifth Ave., S., Birmingham 2, Ala.
Conveyors—Belt, Screw, Flight, and Underground Mine; Elevators—Bucket and Screw; Feeders—Apron, Belt, Reciprocating, Table, and Screw; Drives—V-Belts, Chains and Sprockets, Gears and Speed Reducers

Contractors and Engineers Magazine
470 Fourth Ave., New York 16, N. Y.
Magazine of Modern Construction

Cross Engineering Co.
P. O. Box 507, Carbondale, Pa.
Cross Perforated Steel Segments, Sections, Decks, for Vibrating, Shaking, Revolving, and Other Types of Screening Equipment

Cummins Engine Co., Inc.
Fifth and Union Sts., Columbus, Ind.
Lightweight Highspeed Diesel Engines (60-600 Hp.) for: On-Highway Trucks, Off-Highway Trucks, Buses, Tractors, Earthmovers, Shovels, Cranes, Industrial and Switcher Locomotives, Air Compressors, Logging Yarders and Loaders, Oil Well Drilling Rigs, Centrifugal Pumps, Generator Sets and Power Units, Work Boats and Pleasure Craft

Dart Truck Co.
2623 Oak St., Kansas City 8, Mo.
Off-Highway Trucks—End, Side, Bottom Dumps

Deister Machine Co.
1933 East Wayne St., Fort Wayne 4, Ind.
Deister Vibrating Screens, Classifiers, Washing Equipment

Detroit Diesel Engine Division
General Motors Corp.
13400 West Outer Drive, Detroit 28, Mich.
Light Weight, Compact 2 Cycle Diesel Engines; Electric Generator Sets

Diamond Iron Works
Division Goodman Manufacturing Co.
Halsted Street & 48th Place, Chicago 9, Ill.
Jaw and Roll Crushers; Vibrator, Revolving, and Scrubber Screens; Drag Washers; Bucket Elevators; Belt Conveyors; Bins; Apron and Plate Feeders; Portable Gravel and Rock Crushing, Screening, and Washing Plants; Stationary Crushing, Screening, and Washing Plants; Hammermills

Drill Carrier Corp.
1701 Shenandoah Ave., N. W., Roanoke, Va.
"Air-Trac" Drill Carrier

Du Pont Company of Canada Limited
85 Eglinton Ave., Toronto, Ont., Canada
Explosives and Blasting Supplies

Du Pont, E. I., de Nemours & Co.
Wilmington 98, Del.
Explosives and Blasting Supplies

Dustex Corp.
1758 Walden Ave., Buffalo 25, N. Y.
Dust Collecting Equipment; Dust Control Systems; Feeders

Eagle Crusher Co., Inc.
900 Harding Way East, Galion, Ohio
Crushers, Pulverizers, Hammermills, 4-cage Disintegrating Mills

Eagle Iron Works
129 Holcomb Ave., Des Moines 13, Iowa
Fine Material Screw Washers — Classifiers — Dehydrators; Coarse Material Screw and Log Washers — Dewaterers; Water Scalping and Fine Material Settling Tanks; Drop Balls — Ni-Hard and Semi-Steel; "Swintek" Screen Chain Cutter Dredging Ladders; Revolving Cutter Head Dredging Ladders

Easton Car & Construction Co.
Easton, Pa.
Off-Highway Transportation: Dump Trailers, Truck Bodies, and Cars for Mines, Quarries, and Earth Moving

Electric Steel Foundry Co.
2141 N. W. 25th Ave., Portland 10, Oreg., and 1017 Griggs St., Danville, Ill.
Dragline Buckets, Shovel Dippers, Bucket Teeth, Crusher Wearing Parts, Cutting Edges and End Bits

Ensign-Bickford Co.
Simsbury, Conn.
Primacord-Bickford Detonating Fuse and Safety Fuse

Euclid Division
General Motors Corp.
1361 Chardon Road, Cleveland 17, Ohio
Heavy-Duty Trucks and Dump Trailers for "Off-Highway" Hauls, Loaders for Earth Excavation, Single and Twin Engine Earth Moving Scrapers, Crawler Tractors

Manufacturers Division — National Crushed Stone Association

(continued)

Frog, Switch & Mfg. Co.
Manganese Steel Department
Carlisle, Pa.
"Indian Brand" Manganese Steel Castings for all Types of Jaw, Gyratory, and Pulverizing Crushers; Dippers, Teeth, Treads, and Other Parts for Power Excavating Equipment; and Other Miscellaneous Manganese Steel Castings. Manufacturers and Fabricators of Railroad and Mine Frogs, Switches, and Crossings

General Electric Co.
1 River Road, Schenectady 5, N. Y.
Electric Motors, Controls, Locomotives, Welding Equipment, Coordinated Electric Drives for: Shovels, Drag Lines, Conveyors, Hoists, Cranes, Crushers, Screens, Etc.; Coordinated Power Generating and Distributing Systems Including Generators, Switchgear, Transformers, Cable, Cable Skids, Load Center Substations

Gill Rock Drill Co., Inc.
Lebanon, Pa.
Well Drill Tools and Supplies

Goodrich, B. F., Industrial Products Co.
500 S. Main St., Akron, Ohio
Belting—Conveyor and V-Belts, Hose, and Industrial Rubber Products

Goodyear Tire & Rubber Co., Inc.
Akron 16, Ohio
Airfoam; Industrial Rubber Products—Belting (Conveyor, Elevator, Transmission), Hose (Air, Water, Steam, Suction, Miscellaneous); Chute Lining (Rubber); Rims (Truck and Tractor); Storage Batteries (Automobile, Truck, Tractor); Tires (Automobile, Truck, Off-the-Road); Tubes (Automobile, Truck, Off-the-Road, LifeGuard, Safety Tubes, Puncture Seal Tubes)

Gulf Oil Corp.
Gulf Refining Co.
Gulf Bldg., Pittsburgh 19, Pa.
Lubricating Oils, Greases, Gasoline and Diesel Fuels

Haiss, George, Mfg. Co., Inc.
Division of Pettibone Mulliken Corp.
5720 Empire State Bldg., New York 1, N. Y.
Bucket Loaders, Buckets, Portable and Stationary Conveyors, Car Unloaders

Harnischfeger Corp.
4400 West National Ave., Milwaukee 46, Wis.
A Complete Line of Power Excavating Equipment, Overhead Cranes, Hoists, Welders, Electrodes, Motors and Generators, Diesel Engines

HarriSteel Products Co.
420 Lexington Ave., New York 17, N. Y.
Woven Wire Screen Cloth

Hayward Co.
50 Church St., New York 7, N. Y.
Orange Peel Buckets, Clam Shell Buckets, Electric Motor Buckets, Automatic Take-up Reels

Heidenreich, E. Lee, Jr.
Consulting Engineers
75 Second St., Newburgh, N. Y.
Plant Layout, Design, Supervision; Open Pit Quarry Surveys; Appraisals — Plant and Property

Hendrick Mfg. Co.
Carbondale, Pa.
Perforated Metal Screens, Perforated Plates for Vibrating, Shaking, and Revolving Screens; Elevator Buckets; Test Screens; Wedge Slot Screens; Wedge Wire Screens; Open Steel Floor Grating

Hercules Powder Co.
Wilmington 99, Del.
Explosives and Blasting Supplies

Hetherington & Berner Inc.
701-745 Kentucky Ave., Indianapolis 7, Ind.
Asphalt Paving Machinery, Sand and Stone Dryers

Hewitt-Robins Incorporated
666 Glenbrook Road, Stamford, Conn.
Belt Conveyors (Belting and Machinery); Belt and Bucket Elevators; Car Shakeouts; Feeders; Industrial Hose; Screen Cloth; Sectional Conveyors; Skip Hoists; Stackers; Transmission Belting; Vibrating Conveyors, Feeders, and Screens; Design and Construction of Complete Plants; Molded Rubber Goods; Sheet Packing; Transmission Belting; Dewaterizers; Wire Conveyor Belts; Speed Reducers; Gears; Pulleys; Sheaves; Couplings

Howe Scale Co.
Strongs Ave., Rutland, Vt.
Scales, Static Weighing and Motion Weighing Devices, Automatic Batching Equipment, and Hand Trucks

Hoyt Wire Cloth Co.
Abraso St., off Manheim Pike, Lancaster, Pa.
Aggregate Wire Screens Made of Supertough, Abraso, and Stainless Steel Wire—Smoothtop, Longslot, Oblong Space, and Double Crimp Construction—For All Makes of Vibrators

Hughes Tool Co.
P. O. Box 2539, Houston 1, Texas
Bits—Rock

Illinois Powder Mfg. Co.
506 Olive St., St. Louis 1, Mo.
Gold Medal Explosives

Ingersoll-Rand Co.
11 Broadway, New York 4, N. Y.
Rock Drills, Paving Breakers, Paving Breaker Accessories, Quarrymaster Drills, Drillmasters, Carset Bits, Jackbits, Bit Reconditioning Equipment, Portable and Stationary Air Compressors, Air Hoists, Slusher Hoists, Pneumatic Tools, Centrifugal Pumps, Diesel and Gas Engines

Insley Manufacturing Corp.
801 North Olney St., Indianapolis 6, Ind.
1/2 to 1 Cu. Yd. Cranes and Shovels—5 to 35 Tons Capacity, Rubber or Crawler Mounting; Concrete Carts and Buckets

Manufacturers Division – National Crushed Stone Association
(continued)

International Harvester Co.
Construction Equipment Division
P. O. Box 270, Melrose Park, Ill.
Tractors (Crawlers) and Equipment; Off-Highway Trucks; Power Units—Carbureted and Diesel

Iowa Manufacturing Co.
916 16th St., N.E., Cedar Rapids, Iowa
Rock and Gravel Crushing, Screening, Conveying and Washing Plants, Asphalt Plants, Stabilizer Plants, Impact Breakers, Screens, Elevators, Conveyors, Portable and Stationary Equipment, Hammermills, Bins

Jaeger Machine Co.
550 West Spring St., Columbus 16, Ohio
Portable and Stationary Air Compressors, Self-Priming Pumps, Truck Mixers, Concrete Mixers, Road Paving Machinery, Hoists and Towers; Rubber-Tired, Front End Loaders

Jeffrey Manufacturing Co.
East First Ave., Columbus 16, Ohio
Elevator Buckets; Car Pullers; Chains; Conveyors: Belt, Drag, Apron, Vibrating; Idlers; Crushers; Pulverizers; Elevators; Feeders; Pillow Blocks; Stationary Plants; Screens

Johnson-March Corp.
1724 Chestnut St., Philadelphia 3, Pa.
Dust Control Engineers, Chem-Jet Dust Control Systems, Gas Scrubbers

Joy Manufacturing Co.
333 Henry W. Oliver Bldg., Pittsburgh 22, Pa.
Drills: Blast-Hole, Wagon, Rock, and Core; Air Compressors: Portable, Stationary, and Semi-Portable; Aftercoolers; Portable Blowers; Carpullers; Hoists; Multi-Purpose and Portable Rock Loaders; Air Motors; Trench Diggers; Belt Conveyors; "Spaders"; "String-a-Lite" (Safety-Lighting-Cable); Backfill Tampers; Drill Bits: Rock and Core

Kennedy-Van Saun Mfg. & Eng. Corp.
2 Park Ave., New York 16, N. Y.
Crushing, Screening, Washing, Conveying, Elevating, Grinding, Complete Cement Plants, Complete Lime Plants, Complete Lightweight Aggregate Plants, Synchronous Motors, Air Activated Containers for Transportation of Pulverized Material, Cement Pumps, and Power Plant Equipment

Kensington Steel
Division of Poor & Co.
505 Kensington Ave., Chicago 28, Ill.
Oro Alloy and Manganese Steel Castings: For Shovels—Dipper Teeth, Crawler Treads, Rollers, Sprockets; For Crushers—Jaw Plates, Concaves, Mantles, Bowl Liners; For Pulverizers—Hammers, Grate Bars and Liners; For Elevators and Conveyors—Chain, Sprockets, Buckets; For Tractors—Rail Links and Grouser Plates; Drag Line Chain

King Powder Co., Inc.
Cincinnati, Ohio
Detonite, Dynamites, and Blasting Supplies

Koehring Co.
3026 West Concordia Ave., Milwaukee 16, Wis.
Excavating, Hauling, and Concrete Equipment

Linde Air Products Co., Division of Union Carbide and Carbon Corp.
30 East 42nd St., New York 17, N. Y.
Oxygen, Acetylene, Welding and Jet Piercing Equipment and Supplies

Link-Belt Co.
300 West Pershing Road, Chicago 9, Ill.
Complete Stone Preparation Plants; Conveyors, Elevators, Screens, Washing Equipment, and Power Transmission Equipment

Link-Belt Speeder Corp.
1201 Sixth St., S. W., Cedar Rapids, Iowa
Complete Line of Speed-o-Matic Power Hydraulically Controlled Cranes, Shovels, Hoes, Draglines, and Clamshells, 1/2 to 3-Yd. Capacities. Available on Crawler Base or Rubber Tire Mounting. Diesel Pile Hammers

Lippmann Engineering Works, Inc.
4603 W. Mitchell St., Milwaukee 14, Wis.
Primary and Secondary Rock Crushers and Auxiliary Equipment such as Feeders, Screens, Conveyors, Etc., Portable and Stationary Crushing and Washing Plants

Ludlow-Saylor Wire Cloth Co.
634 South Newstead Ave., St. Louis 10, Mo.
Woven Wire Screens and Wire Cloth of Super-Loy, Steel, and All Other Commercial Alloys and Metals

Mack Trucks, Inc.
P. O. Box 311, Somerville, N. J.
On- and Off-Highway Trucks, Tractor-Trailers, Six-Wheelers, from 5 to 100 Tons Capacity, Both Gasoline- and Diesel-Powered

Manganese Steel Forge Co.
Richmond St. & Castor Ave., Phila. 34, Pa.
ROL-MAN 11.00 to 14.00 Per Cent Rolled Manganese Steel Woven and Perforated Screens, and Fabricated Parts for Aggregate Handling Equipment

Marion Power Shovel Co.
Division of Universal Marion Corp.
617 West Center St., Marion, Ohio
Power Shovels, Draglines, Cranes, Truck Cranes—From 1/2 to 75 Yd.

McLanahan & Stone Corp.
252 Wall St., Hollidaysburg, Pa.
Complete Pit, Mine, and Quarry Equipment—Crushers, Washers, Screens, Feeders, Etc., Semi-Portable Plants

Mercer Rubber Co.
136 Mercer St., Hamilton Square, N. J.
Belting—Conveyor, Elevator, and Transmission; Hose—Air, Water, Steam, Suction, Sandblast, Miscellaneous; Rubber Chute Lining

Manufacturers Division — National Crushed Stone Association
(continued)

Murphy Diesel Co.
5317 West Burnham St., Milwaukee 14, Wis.
Engines—Industrial Engine, and Power Units for Operation on Diesel and Dual Fuel Engines. Generator Sets, AC and DC from 64 Kw. to 165 Kw. Mech-Elec Unit—Combination Mechanical and Electric Power Furnished Simultaneously

New York Rubber Corp.
100 Park Ave., New York 17, N. Y.
Conveyor Belting: Stonore, Dependable, and Cameo Grades; Transmission Belting: Silver Duck Duroflex, Soft Duck Rugged, Commercial Grade Tractor

Nordberg Mfg. Co.
Milwaukee 1, Wis.
Symons Cone Crushers, and Symons Gyratory and Impact Crushers; Gyradisc Crushers; Grinding Mills; Stone Plant and Cement Mill Machinery; Vibrating Screens and Grizzlies; Diesel Engines and Diesel Generator Units; Mine Hoists; Railway Track Maintenance Machinery

Northern Blower Co.
6409 Barberton Ave., Cleveland 2, Ohio
Dust Collecting Systems, Fans—Exhaust and Blower

Northwest Engineering Co.
135 South LaSalle St., Chicago 3, Ill.
Shovels, Cranes, Draglines, Pullshovels—Crawler and Truck Mounted

Olin Mathieson Chemical Corp.
Explosives Division
East Alton, Ill.
Explosives, Blasting Caps, Blasting Accessories

Pennsylvania Crusher Division
Bath Iron Works Corp.
323 South Matlack St., West Chester, Pa.
Single Roll Crushers, Impactors, Reversible Hammermills, Ring Type Granulators, Kue-Ken Jaw Crushers, Kue-Ken Gyratories, Non-Clog and Standard One-Way Hammermills

Pettibone Mulliken Corp.
4710 West Division St., Chicago 51, Ill.
Material Handling Buckets, Clamshells, Draglines, Pullshovels, Dippers, Shovel Dippers, Pumps, Front End Loaders, Bucket Conveyor Loaders, Fork and Bucket Loaders, Speed Swing Loaders, Speed Swing Yard Cranes, Motor Graders, Manganese Steel Castings

Pioneer Engineering Works, Inc.
3200 Como Ave., Minneapolis 14, Minn.
Jaw Crushers, Roll Crushers (Twin and Tripple), Impact Crushers, Vibrating and Revolving Screens, Feeders (Reciprocating, Apron, and Pioneer Oro Manganese Steel), Belt Conveyors, Idlers, Accessories and Trucks, Portable and Stationary Crushing and Screening Plants, Washing Plants, Mining Equipment, Cement and Lime Equipment, Asphalt Plants, Mixers, Dryers and Pavers

Pit and Quarry Publications, Inc.
431 South Dearborn St., Chicago 5, Ill.
Pit and Quarry, Pit and Quarry Handbook, Pit and Quarry Directory, Concrete Manufacturer, Concrete Industries Yearbook, Equipment Distributor's Digest

Productive Equipment Corp.
2926 West Lake St., Chicago 12, Ill.
Vibrating Screens

Quaker Rubber Division
H. K. Porter Co., Inc.,
Tacony and Comly Sts., Philadelphia 24, Pa.
Conveyor Belts, Hose, and Packings

Radio Corporation of America
Inspection and Control Section
Front and Cooper Sts., Bldg. 15-1
Camden 2, N. J.
Tramp Metal Detectors

Rock Products and Concrete Products
79 West Monroe St., Chicago 3, Ill.

Rogers Iron Works Co.
11th & Pearl Sts., Joplin, Mo.
Jaw Crushers, Roll Crushers, Hammermills, Vibrating Screens, Revolving Screens and Scrubbers, Apron Feeders, Reciprocating Feeders, Roll Grizzlys, Conveyors, Elevators, Portable and Stationary Crushing and Screening Plants, Mine Hoists, Drill Jumbos and Underground Loaders

Schramm, Inc.
West Chester, Pa.
Air Compressors, Rotary Drills, Pneumatic Drills, Etc.

Screen Equipment Co., Inc.
1754 Walden Ave., Buffalo 25, N. Y.
Seco Vibrating Screens; Scales—Industrial, Aggregates, Truck

Simplicity Engineering Co.
Durand, Mich.
Simplicity Gyrating Screens, Horizontal Screens, Simpli-Flo Screens, Tray Type Screens, Heavy Duty Scalpers, D'Watering Wheels, D'Centegrators, Vibrating Feeders, Vibrating Pan Conveyors, Car Shake-Outs, Woven Wire Screen Cloth, Grizzly Feeders

SKF Industries, Inc.
Front St. and Erie Ave.,
P. O. Box 6731, Philadelphia 32, Pa.
Anti-Friction Bearings—Self-Aligning Ball, Single Row Deep Groove Ball, Angular Contact Ball, Double Row Deep Groove Ball, Spherical Roller, Cylindrical Roller, Ball Thrust, Spherical Roller Thrust; Tapered Roller Bearings; Pillow Block and Flanged Housings—Ball and Roller

Manufacturers Division — National Crushed Stone Association

(concluded)

Smith Engineering Works
532 East Capitol Drive, Milwaukee 12, Wis.
Gyratory, Gyrasphere, Jaw and Roll Crushers, Vibrating and Rotary Screens, Gravel Washing and Sand Settling Equipment, Elevators and Conveyors, Feeders, Bin Gates, and Portable Crushing and Screening Plants

Stedman Foundry & Machine Co., Inc.
Aurora, Ind.
Stedman Impact-Type Selective Reduction Crushers, 2-Stage Swing Hammer Limestone Pulverizers, Multi-Cage Limestone Pulverizers, Vibrating Screens

Stephens-Adamson Mfg. Co.
Aurora, Ill.
Belt Conveyors, Pan Conveyors, Bucket Elevators, "Amsco" Manganese Steel Pan Feeders, Vibrating Screens, Belt Conveyor Carriers, Bin Gates, Car Pullers, "Sealmaster" Ball Bearing Units, "Saco" Speed Reducers, and Complete Engineered Stone Handling Plants

Taylor-Wharton Co.
Division Harsco Corp.
High Bridge, N. J.
Manganese and Other Special Alloy Steel and Iron Castings; Dipper Teeth, Fronts and Lips; Crawler Treads; Jaw and Cheek Plates; Mantles and Concaves; Pulverizer Hammers and Liners; Asphalt Mixer Liners and Tips; Manganese Nickel Steel Welding Rod and Plate; Elevator, Conveyor and Dredge Buckets

Thew Shovel Co.
East 28th St. and Fulton Rd., Lorain, Ohio
"Lorain" Power Shovels, Cranes, Draglines, Clamshells, Hoes, Scoop Shovels on Crawlers and Rubber-Tire Mountings. Diesel, Electric, and Gasoline, 3/8 to 2-1/2 Yd. Capacities

Thor Power Tool Co.
Prudential Plaza, Chicago 1, Ill.
Wagon Drills, Rock Drills, Sump Pumps, Clay Diggers, Paving Breakers, Quarry Bars, Sinker Legs, Drifters, Rock Drilling Jumbos, Raiser Legs, Push Feed Rock Drills, Air and Electric Tools, Accessories

Torrington Co.
Bantam Bearings Division
3702 West Sample St., South Bend 21, Ind.
Anti-Friction Bearings; Self-Aligning Spherical, Tapered, Cylindrical, and Needle Roller; Roller Thrust; Ball Bearings

Travel Drill Co.
P. O. Box 1124, Raleigh, N. C.
"Travel Drill"—Mobile Drill for Secondary Drilling in Quarries and Open Pit Work

Traylor Engineering & Mfg. Co.
Allentown, Pa.
Stone Crushing, Gravel, Lime, and Cement Machinery

Trojan Powder Co.
17 North Seventh St., Allentown, Pa.
Explosives and Blasting Supplies

Tyler, W. S., Co.
3615 Superior Ave., N.E., Cleveland 14, Ohio
Woven Wire Screens; Ty-Rock, Tyler-Niagara and Ty-Rocket (Mechanically Vibrated) Screens; Hum-mer Electric Screens; Ro-Tap Testing Sieve Shakers, Tyler Standard Screen Scale Sieves, U. S. Sieve Series

Universal Engineering Corp.
625 C Ave., N.W., Cedar Rapids, Iowa
Jaw Crushers, Roll Crushers, TwinDual Roll Crushers, Hammermills, Impact Breakers, Pulverizers, Bins, Conveyors, Feeders, Screens, Scrubbers. Bulldog Non-Clog Moving Breaker Plate and Stationary Breaker Plate Hammermills, Center Feed Hammermills. A Complete Line of Stationary and Portable Crushing, Screening, Washing, and Loading Equipment for Rock, Gravel, Sand, and Ore. Aglime Plants. Asphalt Plants

Vibration Measurement Engineers
725 Oakton St., Evanston, Ill.
Seismographic and Airblast Measurements, Seismological Engineering, Blasting Complaint Investigations, Expert Testimony in Blasting Litigation; Nation-wide Coverage; A Complete Seismograph Rental and Record Analysis Service with "Seismolog"

Werco Steel Co.
2151 East 83rd St., Chicago 17, Ill.
Castings—Manganese, Alloy Steel; Screen Plates—Perforated Steel Screen Sections and Decks; Buckets; Chains; Belt Conveyors, Idlers; Dipper—Shovel; Drop Balls; Wire Cloth; Wire Rope and Related Products; Crushers, Pulverizers

White Motor Co.
842 East 79th St., Cleveland 1, Ohio
On- and Off-Highway Trucks and Tractors—Gasoline- and Diesel-Powered; Industrial Engines—Gasoline and Diesel; Power Units, Axles, Special Machine Assemblies; Crane and Shovel Carriers; Power Generating and Distributing Systems; Batteries; All Classes of Maintenance and Repair Services

White Motor Co.
Autocar Division
Exton, Pa.
Motor Trucks

Wickwire Spencer Steel Division
Colorado Fuel and Iron Corp.
575 Madison Ave., New York 22, N. Y.
Wire Rope, Vibrating and Space Screens, Screen Plate—Perforated Steel

Williams Patent Crusher & Pulverizer Co.
2701-2723 North Broadway, St. Louis 6, Mo.
Hammer Mills, Crushers, Pulverizers, Roller Mills, Reversible Impactors, and Vibrating Screens, and Air Separators

NCSA

NATIONAL CRUSHED STONE ASSOCIATION · 1918 ·